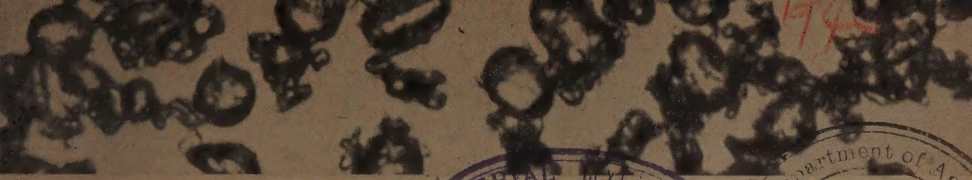

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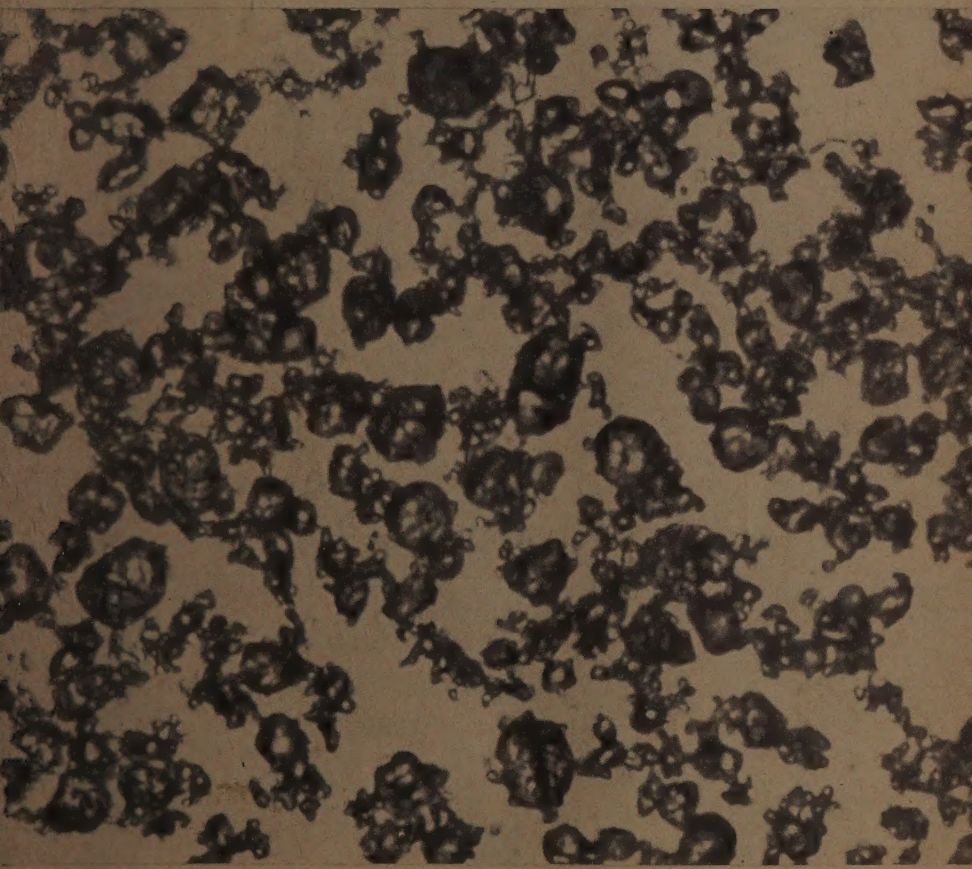
SULFUR SPRAYS

BY A. B. GROVES



VIRGINIA POLYTECHNIC INSTITUTE
VIRGINIA AGRICULTURAL EXPERIMENT STATION
BLACKSBURG, VIRGINIA

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SULFUR SPRAYS[1]

By A. B. Groves, *Assistant Plant Pathologist*

INTRODUCTION

Sulfur, either in its simple elemental form or as the essential component of some complex compound, is perhaps the most important fungicide used in American horticulture today. The material has served agriculture as a fungicide, insecticide, and disinfectant for over a century. The purpose of this bulletin is to organize and present to Virginia fruit growers the more pertinent information about sulfur materials and their usefulness as related to the needs of fruit growers. The various types of products, their characteristics, adaptation, and limitations are presented and discussed in such detail as seems necessary to form the basis for an individual's selection to meet his particular needs.

Sulfur, or brimstone, is a natural mineral occurring both in its uncombined or elemental form and in combined forms such as gypsum. Much of the sulfur of commerce is of volcanic origin, although this source is of less importance than it was a few decades ago. Most of the sulfur used in this country comes from underground beds in the Gulf Coast region. The material is of a high degree of purity as supplied to the insecticide-fungicide processing trade, and is the basic product from which virtually all except the by-product sulfurs are manufactured.

The field of adaptation of the sulfur and copper fungicides in the fruit industry overlap to a certain extent, and in view of the more critical supply situation with respect to copper, it seems appropriate to give some attention to those places in the disease-control schedule where sulfur may be satisfactorily substituted for copper. To a certain extent the present hesitant attitude toward substituting another material for copper is based only upon the consideration of lime-sulfur as an alternative, or upon some unsatisfactory experience with proprietary materials. An attempt will be made here to define the satisfactory limits of usefulness and safety of the various types of sulfur materials.

TYPES AND FORMS OF SULFUR FUNGICIDES

Sulfur is utilized as a fungicide in two forms or states; the uncombined or elemental form, commonly represented by the dry wettable and flotation sulfurs; and the chemically combined form of which lime-sulfur is the most important product. There are several types of products and these are dis-

[1] Paper 121 from the Section of Botany and Plant Pathology, Biology Department, Virginia Agricultural Experiment Station.
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cussed separately. The terms "elemental" and "wettable" are to some extent used interchangeably in this bulletin because such is common practice among growers. The term elemental in a strict sense signifies the chemically uncombined state; the term wettable simply indicates that the product will mix with water. Pure ground sulfur will not do so. Actually all dry sulfur fungicides with the exception of dry lime-sulfur are both elemental and wettable. Dry lime-sulfur is principally soluble but partly wettable, flotation sulfur is elemental but already wet and therefore the term wettable is superfluous. For all practical purposes, lime-sulfur is the only combined sulfur material worthy of consideration here. There are other forms, but they are not of sufficient importance to the fruit industry at present to justify an extensive discussion.

The term "combined sulfurs" is used to describe lime-sulfur, liver of sulfur and sodium sulfur, fungicides in which the sulfur occurs in chemical combination, and to distinguish such materials from those in which sulfur is present in the pure or elemental state. The calcium polysulfides constitute the principal combined sulfur compounds utilized as a fungicide, and are commonly sold in the liquid form, or more accurately, in water solution. Dry forms of the combined sulfurs available are discussed briefly in a later paragraph. The sodium and potassium polysulfides are occasionally used in spraying, and calcium monosulfide was once used to some extent but lost favor because of low effectiveness and mechanical difficulties resulting from its use.

Preparation and Dilution of Lime-Sulfur

Lime-sulfur is produced by heating a watery mixture of lime and ground sulfur until the sulfur has reacted to form a solution of calcium polysulfides, commonly known as liquid lime-sulfur. Most of the lime-sulfur used in Virginia today is a commercially prepared product. The laborious task of preparing and cooking the material is thus avoided, and a more nearly uniform, sediment-free product is obtained. However, some growers still prefer to prepare their own lime-sulfur, and the common method of preparation is given. Stone lime and coarsely ground (80 mesh) sulfur are commonly utilized, although hydrated lime may be used if the quantity is increased one third by weight. One part of stone lime is used for each two parts of sulfur, although the amount of water used may vary according to the test of the product desired. The most commonly used formulas require either 62½ pounds of stone or unslaked lime and 125 pounds of sulfur to each 50 gallons of water; or 50 pounds of lime and 100 pounds of sulfur to 50 gallons of water. The lime is slaked with approximately one-half of the water in the kettle or other container in which the mixture is to be cooked. The sulfur is stirred in and the remainder of the water added, and the mixture cooked by boiling until all the sulfur is dissolved and the

solution clear. The mixture must be stirred constantly and water added to replace that lost by evaporation. There will be more or less undissolved sludge in the bottom of the cooker, and in order to obtain a clear solution the lime-sulfur is either drained off into a larger tank and allowed to settle before being put into barrels, or it may be strained and poured directly into the storage containers. The straining or filtering equipment available on the farm will not produce a product free of sediment, however, as can be done with commercial equipment. The solution must be tested with a Baumé scale hydrometer and the rate of dilution for use adjusted accordingly. A lime-sulfur dilution table is given for reference.

Table 1.—Lime-Sulfur dilution rates.

Degrees Baume test of concentrate at 60° F.	Amount to use per 100 gallons of spray		
	Dormant spraying to control scale	Growing season spraying	
		Before bloom	After bloom
	Gallons	*Quarts*	*Quarts*
35	10½	7	5¼
34	11	7⅓	5½
33	11½	7¾	5¾
32	12	8	6
31	12½	8⅓	6¼
30	13	8¾	6½
29	13½	9	6¾
28	14	9½	7¼
27	14½	10	7½
26	15	10½	7¾
25	16	11	8¼
24	17	11⅓	8½
23	17½	12	9
22	18½	12¾	9½
21	Not suitable	13½	10
20	Not suitable	14	10½

Adaptability and Disadvantages of Lime-Sulfur

Liquid lime-sulfur is the most effective fungicide for early use on apples, and because it is so highly effective in preventing primary apple scab infections it must be considered the first choice where experience has shown scab to be a major annual problem. The material is also effective against most early season infections other than cedar rust, which presents a special problem. Lime-sulfur is the only fungicide that can be reasonably depended upon to destroy or "burn out" scab infections after they have developed. The elemental sulfurs have no real eradicative powers; they are useful as infection preventives only.

Lime-sulfur at summer-spray strength is effective against the newly hatched red mite nymphs, but not against the older ones. The mites hatch over a period of several days, however, and the possible value of lime-sulfur in checking an outbreak when other factors are favorable has not been demonstrated.

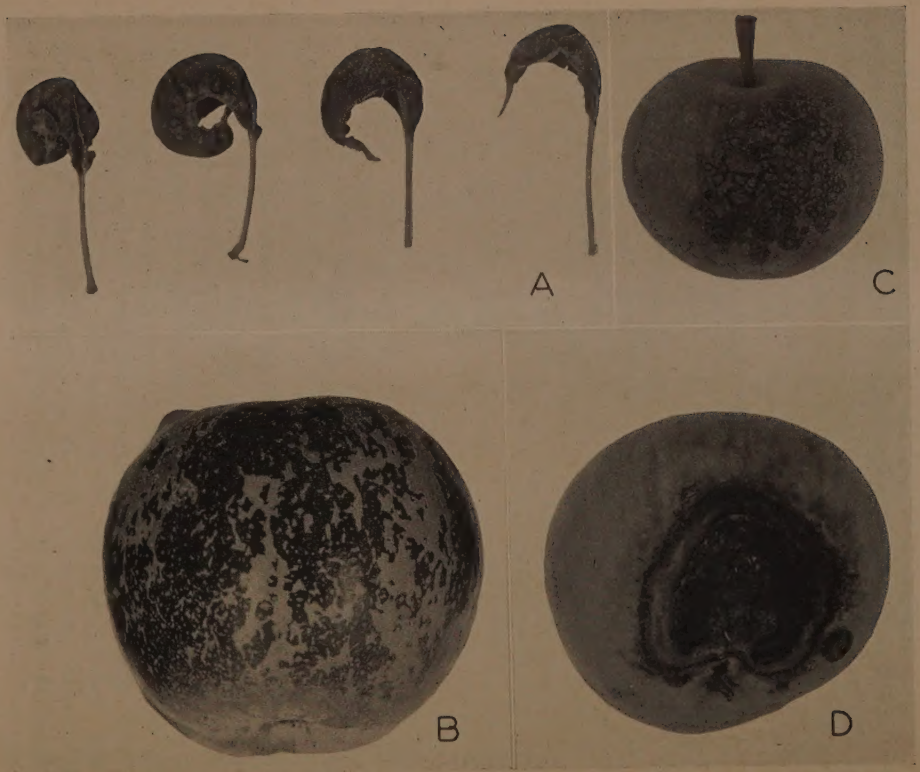

Figure 1.—Lime-sulfur spray injuries. A—Young apple leaves deformed by marginal burning. B—Russet pattern typical of early season injury. C—Side russet developing from sulfur scald resulting from first cover spray. D—Severe sulfur-sun scald in midsummer.

Lime-sulfur is the cheapest effective material that the grower uses. The low cost and high effectiveness of lime-sulfur constitute its major advantages as a fungicide.

Lime-sulfur is not always the first choice as a fungicide for all apple varieties or under all situations, however, particularly where fruit and foliage injury will likely result from its use. Such injury is frequently severe and in some orchards is a more serious problem than the occasional outbreak of scab. The fruit may be injured in its earliest stages (Fig. 1-B) or it may be scalded when fairly well developed (Fig. 1-C). Lime-sulfur may also reduce the set of fruit through what is known as "sulfur shock," a poorly understood consequence of the application of lime-sulfur to young apple buds. Sulfur shock is discussed more in detail under the elemental sulfurs.

Lime-sulfur reduces the effectiveness of lead arsenate by at least one-third, frequently even more. This is a serious factor where the best efforts are required to keep codling moth in check, and will tend to make codling moth control more of a problem in lightly infested orchards.

Lime-sulfur tends to increase arsenical injury, particularly calyx burn. Whether this is due to the formation of lead sulfide, calcium arsenate, or other compounds is not clear. Lime-sulfur is not a safe cover fungicide and is seldom utilized as such.

Lime-sulfur is not suitable for use on peaches except during the dormant season when used for the control of San Jose scale and peach leaf curl.

Dry Lime-Sulfur

Dry lime-sulfur is prepared from liquid lime-sulfur although the reconstituted product formed by dissolving the dry material in water is not identical with the original product. Certain chemical changes attend the drying process despite the fact that a stabilizer is added to prevent or retard such changes, and the character of the spray is modified. The changes effected are not wholly undesirable, however, for dry lime-sulfur tends to be less injurious than liquid lime-sulfur. The changes also render the material less effective as a fungicide, although it remains a good one. The material is not as satisfactory a scalecide as the liquid form and must be used on an active ingredient-equivalent basis to be at all effective. Four pounds of dry lime-sulfur contains an amount of calcium polysulfides equal to that in one gallon of liquid lime-sulfur. When used as a fungicide, however, dry lime-sulfur is seldom recommended or used on an equivalent basis with the liquid form.

The reasons for the production of a dry form of lime-sulfur are readily apparent. Liquid lime-sulfur is bulky and expensive to ship because of the water content; containers must be provided for its distribution and these

must be accounted for and returned; filled containers are heavy and difficult to handle; storage of the product requires storage space out of proportion to the value of the product; it is not readily merchandised in small quantities. Dry lime-sulfur is free of most of these disadvantages but will not keep indefinitely in storage. The material gradually reverts to the elemental form and hardens in the bag, thus becoming unsuitable for use. Dry lime-sulfur is irritating to the skin of some persons and is best handled in open air to avoid nasal irritation.

The sodium polysulfides are used for the same purposes as ordinary lime-sulfur when used at all, but are seldom employed because they offer no real advantages, and have a greater tendency to cause spray injuries. They are most commonly used during the dormant period, are moderately effective against San Jose scale, and very effective against peach leaf curl. A liquid form is widely distributed under the trade name of Sulfocide, and a dry form is offered as Soluble Sulfur. Similar products under other trade names may be offered in some localities. The sodium polysulfides do not lend themselves to home preparation, largely because of the expense and difficulties attendant upon handling large quantities of caustic soda.

The Elemental or Wettable Sulfurs

The term "elemental" signifies that sulfur is present in its pure, uncombined state. Finely divided sulfur is an insoluble powder, and in order to render it suitable for spray use, it is rendered "wettable" by the addition of certain compounds known as wetting agents. The terms elemental and wettable are not truly synonymous, but are descriptive terms applying to different characters of the product. Actually, most of the products described under this heading are both elemental and wettable; only flotation sulfur which is already wet, is not really "wettable." However, because of the widespread usage of the term "wettable sulfur" in speaking of any dry or paste sulfur fungicide, the two terms are used more or less interchangeably in this publication.

Elemental sulfur is available and utilized in several forms, principally dry-mix sulfur-lime, the proprietary products which for the most part are almost 100 percent sulfur made wettable, self-boiled lime-sulfur, and a few special products. The character, preparation, and use of these are discussed in some detail.

Non-Proprietary Products

Self-boiled lime-sulfur is at present little used, although an occasional grower prefers and still uses it. Self-boiled lime-sulfur was the first widely accepted elemental sulfur spray and was generally considered superior to the milled sulfur products then available. The material was used principally on peaches, but was occasionally employed on apples because it was less caustic

than liquid lime-sulfur. Self-boiled lime-sulfur is prepared in the following manner. Five pounds of stone lime (burned, unslaked) for each 100 gallons of spray tank capacity is put into a half barrel or other convenient container of adequate size, and sufficient water added to start slaking. An equal amount of sulfur, usually a relatively coarse agricultural grade, is sifted over the slaking lime. The sulfur may be made into a thin paste and poured over

Figure 2.—A—Branch from York tree sprayed with lime-sulfur showing typical foliage injury resulting from repeated applications of liquid lime-sulfur. B—Branch from a nearby York tree sprayed with an elemental sulfur showing no foliage injury.

the slaking lime if preferred. Water is added as needed to keep the lime slaking, care being taken to prevent overheating or burning and yet not "drown" the mass with an excess of water. The mixture is kept stirred and allowed to boil for a moment after slaking is complete to break down all the small lime aggregates possible and to completely divide the sulfur. Additional water is added and the process stopped as soon as a trace of polysulfides or lime-sulfur appears on the surface of the hot mass. The material is then added to the spray tank. The formula given provides the recommended amount of sulfur for use on peaches. The old 8-8-100 formula may be used if preferred, however. No wetting agent is necessary with self-boiled lime-sulfur.

Self-boiled lime-sulfur possesses advantages of cheapness and effectiveness. A cheap, coarse grade of sulfur may be utilized, yet it is reduced to a fine state of division by the heating and slaking process. Balanced against these advantages are the inconvenience and time-consuming nature of the method of preparation. Inexperienced or careless help may burn the mixture or allow it to boil too long and produce too much lime-sulfur, which causes the material to become caustic. The character and freshness of the lime varies and the operator must be able to judge these factors in order to slake it properly and produce a good mix. There is also some unslaked material which must be strained out and discarded with each load. Self-boiled lime-sulfur lost favor many years ago for these reasons, yet it is a good fungicide.

Dry-mix, or New Jersey dry-mix replaced self-boiled lime-sulfur because of its convenience in handling, its uniformity of product, its time saving, and its elimination of much of the personal factor with incompetent help. Dry-mix sulfur-lime is a mixture of a fine grade of milled sulfur, hydrated lime and a wetting agent, usually either calcium caseinate or lignin pitch. The formula most widely used in Virginia contains 8 pounds of sulfur, 4 pounds of lime, and ½ pound of calcium caseinate. Dry-mix is a satisfactory peach fungicide and may be used on apples where the sulfur stock is of satisfactory fineness. The material has been almost entirely replaced by the proprietary sulfur products, principally because of greater convenience, better handling properties, and in most instances, greater fungicidal effectiveness.

Certain home-made wettable sulfurs have been prepared by growers at times when it was necessary to cut costs to an absolute minimum. The mixtures were prepared in either of two ways: (1) by using sulfur dust as a base and adding the necessary wetting agents, or (2) by using mixtures of a dusting sulfur with equal amounts of some proprietary product. A fine grade of dusting sulfur, which usually contains ample conditioning agents may be made wettable by the addition of various wetting agents, such as lignin pitch, soybean flour, fish oil soap, calcium caseinate, or one of several proprietary materials. These are almost universally mixed by adding a wetting agent to a small quantity of water in a suitable container, stirring in

the dusting sulfur until thoroughly wet, and then adding the paste to the spray tank. Mixtures of a proprietary sulfur with a quantity of dusting sulfur, in which the excess amount of wetting agent usually present is utilized to wet additional sulfur, are also best wet in a bucket before adding to the spray tank. Some mixtures will wet readily when added directly to the spray tank, particularly when the dust contains a wetting agent, as is the case with certain products. The merit of such mixtures depends largely upon the character of the sulfur used in their preparation. They will seldom wet with the ease that proprietary products do, and attention must be given to this fact if satisfactory results are to be secured. The amount of wetting agent used should be adjusted so that run-off of the spray is reduced to a practical minimum. It might be well to note that foliage is more readily wet after the leaves are fully grown and somewhat weathered. Wetting of the leaves is, therefore, more difficult early in the season than later.

The Proprietary Sulfurs

The proprietary sulfurs are simply brand-name products, as distinguished from standard materials not commonly sold by brand or trade-marked name. The character of a proprietary sulfur may or may not be unique; many differ only in the name under which they are offered.

The proprietary sulfurs are produced either by some milling or manufacturing process, or as a by-product in the production of coal gas. The nature of these materials will be outlined in the discussion following, and the several types of products classified on the basis of their adaptability as fruit fungicides.

The proprietary wettable sulfurs are essentially a mixture of some finely milled sulfur stock plus small amounts of wetting, dispersing, and conditioning agents. Special additives are sometimes included for some specific purpose, but the basic and effective ingredient remains the same in all, that is, fine elemental sulfur. Flotation sulfur differs radically from the dry wettable products in physical condition, yet its fungicidal ingredient is the same fine elemental sulfur.

The most important single factor in determining the merit of an elemental sulfur fungicide is its fineness. The fungicidal effectiveness of a sulfur material is closely correlated with its fineness. Fine particles also adhere better than large ones. The fineness of a product cannot accurately be judged by feeling, flowability, or dustiness when shaken, all common rule-of-thumb tests; because in reality, these are only rough tests of the amount and type of conditioning agent present. Fineness can be accurately determined only by microscopic examination or other more complicated laboratory techniques. Each milling method tends to produce a typical product and for this reason attention is given to the common methods of fractionation of sulfur and the

type of material produced by each. This information should prove of value in comparing products, for with few exceptions all products produced by any single method are sufficiently similar to justify selection on the basis of cost. There are no products commercially available in Virginia at present which are produced by methods other than those described here.

Fractionation Methods

There are only two types of dry milled sulfurs; those ground in mechanical impact mills of the roller or hammer type, and those ground in the Micronizer mill. The greater portion of all spraying and dusting sulfur is produced by dry milling or grinding in a roller mill. The sulfur is pulverized as it passes between a grinding ring and rapidly revolving steel rollers. The fineness of the final product may be regulated by the adjustment of the special air separator commonly attached to the mill. The greater part of the production of these mills is characterized as a 300- or 325-mesh sulfur, products of moderate fineness. It might be well to note here that actually any sulfur fungicide must be much finer than the actual dimensions of a 325 series sieve opening to be acceptable as a fungicide, but the limitations of the sieve method of measuring are such that finer sieves are impracticable. The use of such terms as "5,000 mesh," etc., do not represent any actual existing sieve, but a theoretical projection on the basis of existing screens. While the use of the high figure may represent an effort to provide a system of measurement in familiar terms, it does not adequately characterize the fineness of division, and hence its use seems unjustified. It is hoped that the information given in this discussion will so clarify the situation that a selection of a suitable product for any purpose may be made without reliance upon such terms.

The conditioning, dispersing, and wetting agents are fed into the mill with the sulfur and milled with it in order to assure thorough mixing and blending of the materials. The finely ground product as recovered in a cyclone or other type collector is ready for bagging and sale. Fixed hammer mills are occasionally used and produce a similar product.

The Micronizer mill is a comparatively recent development, and in principle departs quite radically from the conventional roller and hammer mills. Grinding action in the Micronizer mill is accomplished by the shattering action of innumerable collisions between the sulfur particles themselves as they rotate within a special grinding chamber. The sulfur stock, together with conditioning and wetting additives, are fed into the flat, circular grinding chamber of the mill and rotated at high speed by air jets. The mill also acts as a centrifugal separator, the finest particles being withdrawn from the center of the vortex in the escaping air. The Micronizer mill in general produces the finest dry milled products. There are a number of Micronized

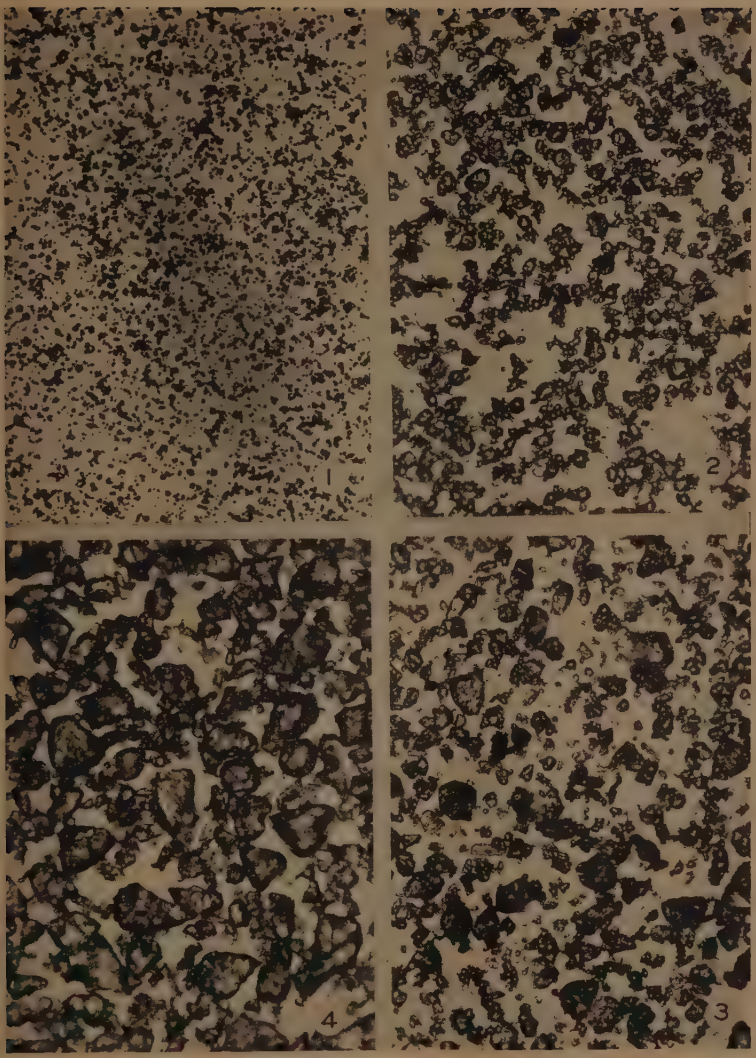

Figure 3.—Sulfur fungicides highly magnified to show relative fineness. 1—Flotation sulfur paste. 2—A Micronized sulfur. 3—A roller mill ground sulfur suitable for cover spray use. 4—A sulfur product suitable for use on peaches.

sulfur products on the market, all essentially the same. Choice between them may be made on the basis of cost.

The Grinrod process is another comparatively new fractionation method which does not employ any grinding process, but the fine state of division produced is attained by the atomization of molten, emulsified sulfur. The Grinrod sulfurs are unique in that the wetting agent is adsorbed onto the surface of each particle during the manufacturing process, and does not occur as a simple mechanical mixture as with most of the dry milled products. Mike sulfur is the only Grinrod product being offered for sale in Virginia at present.

Flotation sulfur is a by-product of the manufacture of coal or artificial gas. Coal contains a small amount of sulfur which is driven off as hydrogen sulfide together with other gasses as the coal is heated in the gas production chambers. Hydrogen sulfide is an offensive odorous and corrosive gas which must be removed before the gas is forced into the mains for consumption. The actual steps by which the sulfur is recovered are complicated, but suffice to say here that it is recovered as a fine sulfur precipitate, which after appropriate filtering and washing is ready for sale. The material is usually offered as a paste of approximately 40 to 45 percent sulfur content. Small amounts of additives are usually added to improve the physical nature of the product, and the paste is beaten or mechanically worked before being put into barrels for shipment and sale.

Flotation sulfur is the finest of the elemental sulfurs, and perhaps has been more widely used by Virginia fruit growers than any other sulfur material. Flotation sulfur is at present offered for sale only as a paste, although dry, wettable forms have been offered in the past, and doubtless will be again when the machinery for such processing is available. The paste material is unquestionably less convenient to use than a dry product, and furthermore cannot be offered or kept in quite as high a degree of uniformity as the dry materials. However, these objections are not serious and the difficulties of mixing are not unreasonable when properly done. Flotation sulfur is most easily mixed in a half barrel or similar container, a small amount of water added and the mixture then stirred with a hoe or strong paddle. Additional water is added until a smooth thin paste is produced, and this is then poured through the spray tank strainer. Some growers prefer to prepare the mixture ahead of time and thus allow it to stand and soak while one spray load is being applied, thus gaining something in time and obtaining a smooth mixture with less stirring. A spray gun may also be used to good advantage in mixing the paste, and is to be recommended where this equipment is on the rig or is readily available. The paste can be quickly broken up by the stream from a spray gun reduced just enough to produce

a narrow cone of spray and held a few inches from the material. Flotation paste cannot be successfully added directly to the spray tank as can the dry materials.

Product Adaptability

The elemental or wettable sulfurs are uniformly less effective than liquid lime-sulfur. They are mild fungicides at best, although there are important differences between them. They are protective fungicides only, having none of the eradicative properties of lime-sulfur. Generally speaking, the finer a sulfur the more effective it is as a fungicide. The elemental sulfurs have, therefore, been classified on this basis and the groups, together with the proprietary products in each, are given.

The flotation sulfurs, of which only two have been widely offered in this region, are the finest products available and are the most widely adaptable of the elemental or wettable sulfurs. Flotation sulfur is suitable for use on apples from the earliest pre-blossom application on the less scabby varieties, and on all varieties in the post-blossom and early cover sprays. Flotation sulfur has been used with success on even the most scabby varieties by some growers. Such use can be recommended only where sprays can be applied within a short interval and thorough coverage obtained. The wettable sulfurs are successful only where spraying is good; they are not for the poor or light sprayer. Flotation sulfur is also suitable for use on peaches for brown rot and scab control.

The Grinrod and Micronized sulfurs principally constitute the second group of wettable sulfurs. Proprietary products include Mike, Flo-Sul, Micro-Spray, 3-Micron, Mico, Mulsoid, and Micronized sulfurs. There may be other similar products which belong in this classification, but have not been included here because of very recent introduction or of changes made since 1943.

Experience has shown that the finest of the dry wettable products have much the same range of usefulness as flotation sulfur, but with a somewhat lower order of effectiveness. Their use except on the less scabby apple varieties is, perhaps, best limited to post-blossom sprays. McIntosh, Delicious, Winesap, and other varieties that are very susceptible to scab should receive the most effective scab fungicides during the early season; therefore, considerable caution should be exercised in using these products under potentially dangerous scab conditions. These sulfurs are well suited for use in all peach sprays where a fungicide is needed.

The third group of sulfurs includes those products milled by conventional roller mill methods, and includes the bulk of the dry wettable sulfurs used by the fruit industry. These products are high grade 325-mesh sulfurs, but are not sufficiently fine for dependable use on apples prior to the cover sprays. They may be safely used in the first and second cover sprays except under unusual or extreme disease conditions. Growers who limit their use

of the wettable sulfurs to the early cover sprays may safely choose from this group of materials. Their earlier use is not to be generally recommended, however, although they are occasionally so used with satisfactory results where there is little scab. They frequently fail to give control where the season is more unfavorable. Products included in this group are Apple Dritomic, Chipman Brand Wettable, Sulforon, and Magnetic Spray. They are generally excellent peach fungicides, although they may be somewhat higher in price than products sold exclusively for use on peaches.

The fourth group includes those products designed and offered principally as peach fungicides. They are relatively coarser materials, and while quite satisfactory for use on the peach, are altogether too coarse and poorly adhesive for use on apples. There is no likelihood that injury to fruit will result from their use, but their adhesiveness on apples and their effectiveness against scab is too low to justify their use when a fungicide is really necessary. Needless to say, any mild material will prove satisfactory where there is nothing to control. This is often the explanation for a grower's satisfaction with a relatively ineffective material. The peach sulfurs include Chipman "95," Crown, Sulfix, Dritomic, Hytox, Virginia Top, and Wet-Spray.

There are some products which do not fall clearly into any of the foregoing categories, and which are described briefly here. Kolofog is a fused sulfur and bentonite product containing approximately 35 percent sulfur and 65 percent bentonite and fungicidally inert ingredients. The material is granular in nature, each granule containing numerous sulfur particles in a bentonite matrix. The granules readily disintegrate in water, the bentonite dispersing into colloidal suspension and releasing the sulfur particles. The sulfur particles are comparatively large, but the bentonite seems to improve their adhesiveness. Certainly the bentonite portion adheres well. Kolofog is quite mild and may be used with assurance of safety on any tender apple variety or on peaches. Kolofog is utilized to some extent in combination with lime-sulfur to serve as a "marker" because of its conspicuous residue. Kolospray contains 85 percent milled sulfur and 15 percent bentonite (plus miscellaneous additives) in a mechanical mixture. There has been no heat fusion as in the case of Kolofog. Kolospray is a mild fungicide falling into the peach fungicide group.

Catalytic sulfur and Pratt's Spray Catalyzer are special wettable products recommended by the manufacturers for use in combination with liquid lime-sulfur. They contain two major ingredients in addition to elemental sulfur; manganese sulfate and casein. These materials are intended to render lime-sulfur less injurious through hastening the normal breakdown of the material in the spray film on the fruit and foliage, and by preventing a reaction between lead arsenate and lime-sulfur while in the spray tank. The first action is particularly desirable where drying conditions are poor, as is often

the case in the early season when trees may remain wet with spray for hours or even over-night. The reaction between lime-sulfur and lead arsenate causes the darkening of the spray solution commonly observed when lead arsenate is added to lime-sulfur. These two "catalytic" materials do accomplish the purpose for which they were intended, but they also reduce the effectiveness of lime-sulfur, and furthermore their protective action is of short duration. This latter shortcoming leads to a delayed development of arsenical injury. The two catalytic sulfur products are intended for use without lime as lime interferes with the action of the manganese sulfate. Since lime is omitted, its more prolonged protective action is lost; therefore, these two products are little used at present.

The practice of using combinations of lime-sulfur and a wettable sulfur has not proved to be a desirable practice in Virginia, and such combinations are now little used. Efforts to promote this practice were made on the supposition that lime-sulfur could be made safer by reducing its strength one-half, and the possible loss in fungicidal value regained by the addition of wettable sulfur. Actually, however, the injurious nature of lime-sulfur was little lessened by the reduction in strength, and the wettable sulfur added little or nothing to the fungicidal strength of even a weak lime-sulfur. The merits of lime-sulfur and the wettable sulfurs are best employed when they are used alone and in conformity with the requirements of a particular situation.

Elemental Sulfurs in the Virginia Spray Program

The elemental sulfurs have certain definite adaptations and advantages as fruit fungicides, as well as certain limitations and disadvantages. The principal advantages of the elemental sulfurs in comparison with lime-sulfur lie in their mildness, their safe character, a lack of pronounced tendency to cause injury to tender fruit and foliage. Liquid lime-sulfur unquestionably causes injury to tender foliage early in the season (Fig. 1-A and Fig. 2-A), particularly under unfavorable weather conditions or when several applications are made at short intervals. Severe injury may also result to older and more resistant foliage where several applications are made.

The elemental sulfurs do not cause "sulfur shock" of the developing, or newly set, fruit buds. Lime-sulfur has been repeatedly shown to have such an effect on fruit buds as a result of applications made just before or shortly after blossoming, causing some to fail to set. This is not a serious factor when there is a good bloom and pollinating conditions are good, for even with this loss too heavy a crop is frequently set. However, there are times when a poor prospect could have been made better by the substitution of an elemental sulfur for liquid lime-sulfur. The shock effect of lime-sulfur is further aggravated by frost, following which the losses due to shock may be heavy enough to seriously reduce the crop. A similar condition frequently

exists in solid blocks of poor self pollinators such as Delicious. The elemental sulfurs are quite bland or mild in comparison with lime-sulfur and are therefore useful in preserving a light bloom, or one that for any reason promises to set lightly.

The foliage on trees sprayed with an elemental sulfur is usually more luxuriant, the leaves larger and with little or no marginal leaf scorch (Fig. 2-B). Anything that contributes favorably to the condition of the foliage must also eventually be reflected in better tree and fruit growth. Apple fruits are frequently injured by lime-sulfur, injury being apparent both in the form of russet resulting from early applications (Fig. 1-B), and later in the season as sulfur sun-scald (Fig. 1-C, D). The elemental sulfurs are much less prone to cause either type of injury, although any sulfur material will aggravate a sun-scalding condition during periods of hot, dry weather.

The elemental sulfurs do not reduce the effectiveness of lead arsenate when used in combination with it, a practice which is necessarily almost universal. This factor alone is frequently the decisive one in the selection of a fungicide.

The elemental sulfurs may be safely used in all cover sprays except when extremely high temperatures prevail. Their use in the second and third cover sprays instead of Bordeaux mixture will help extend the supply of copper sulfate. However, Bordeaux mixture should be used in the final cover spray in June as well as in any second brood cover sprays. No sulfur material can be safely used in combination with, or closely preceding an application of summer oil, and this fact must be borne in mind if oil is to be used for codling moth control.

The principal limitation of usefulness of the elemental sulfurs lies in their only moderate fungicidal effectiveness, particularly against apple scab. However, much criticism has been directed against all elemental sulfur fungicides because of the failure of a few prominent and widely distributed sulfur products which were not among the most effective products available. Flotation sulfur has consistently shown itself to be the most effective of the sulfurs, and is to be recommended where maximum effectiveness is necessary.

The wettable sulfurs are not effective against bitter rot or blotch, of course, nor is lime-sulfur. No sulfur fungicide is satisfactory for the control of these diseases.

The wettable sulfurs tend to adhere rather poorly, thus reducing their effectiveness. They wash off considerably in heavy rains, and therefore coverage must be frequent and thorough if a maximum of protection is to be maintained during critical scab periods.

The wettable sulfurs have generally been higher in cost than lime-sulfur, although the margin of difference has been reduced in recent years until the difference is small. Some growers find the wettable sulfurs objectionably

less convenient to measure or weigh and mix than lime-sulfur, particularly flotation sulfur. This seems largely a matter of personal preference, however, and the importance given this factor will vary accordingly.

Manner and Rate of Usage

The wettable sulfurs are generally used at the rate of 6 pounds per 100 gallons of spray for the early or pre-cover sprays, at 4 pounds in the cover applications. Flotation sulfur is used at approximately an equivalent rate on the basis of dry weight, or 12 and 8 pounds, respectively, per 100 gallons. The sulfur content of the material is below 50 percent, however; so actually it is used at a slightly lower rate than the dry materials.

The wettable sulfurs may be added either directly to the partially filled spray tank as the agitator is running, or they may be pre-mixed in a bucket with a small quantity of water and the resulting thin paste poured into the tank. Either method works well with most materials and water supplies, although the slower wetting materials should preferably be pre-mixed. Products which have a tendency to form lumps, or old materials that have become somewhat lumpy, also should be pre-mixed before being added to the tank. Kolofog, however, should always be added directly to the tank as pre-mixing is very difficult. All pre-mixed material should be put into the tank through the tank strainer to remove remaining unbroken lumps and aggregates which would otherwise accumulate on and clog the feed line strainer. The mixing of flotation sulfur is best accomplished in a half barrel or other large container using a spray gun, heavy paddle, or hoe to break up the paste and incorporate additional water into it, thus making a thin paste which can be poured through the strainer. Flotation sulfur cannot be successfully added directly to the tank, although where the paste is not too dry, it can be put through the strainer with a spray gun. This latter method of incorporation is most adaptable to spray machines having large strainers with deep serrations in the screen.

The adhesive and fungicidal properties of the wettable sulfurs are improved by the use of a small amount of hydrated spray lime. Lime flocculates the spray suspension and gives a better spray deposit as well as seemingly increasing the fungicidal effectiveness of the sulfur. Lime is commonly added when lead arsenate is used in combination with sulfur in order to lessen the danger of arsenical injury. Lime used at pound for pound with the arsenical is sufficient when wettable sulfur is the fungicide being used. There is no need to use two pounds of lime for each pound of lead arsenate with the wettable sulfurs which is the general practice where liquid lime-sulfur is used as the fungicide. The wettable sulfurs may be safely used on apples without lime if lead arsenate is not included; however, because of the beneficial effect of a small amount of lime, its addition is recommended.

The order of addition of materials is generally that of sulfur first, followed by lime and other additives, if any, and finally by the lead arsenate. The elemental sulfurs do not combine with other materials, however; so the order of addition may be changed if desired without deleterious effect.

Various spreader-sticker agents have been offered and sold for use with the wettable sulfurs, as well as with other fungicides and insecticides. The wettable sulfurs are compatible with all commonly used stickers although caution is advised in the use of oil-containing stickers, particularly in warm weather. The use of stickers in combination with wettable sulfurs is of questionable value. This may be due in part to an interference by the stickers with the fungicidal action of sulfur, thus defeating the purpose of their use even though a higher spray deposit is obtained. Sulfur materials are seldom used alone except early in the season, however, and the possible value of spray amendments on the effectiveness of lead arsenate particularly must be considered. With the exception of some oil type products, numerous tests have failed to reveal the beneficial effect of the spreader-sticker agents upon lead arsenate. The ineffectiveness of these materials, or at best an erratic beneficial effect does not seem to justify a general recommendation of their use with sulfurs. They can be safely used where desired as already noted, or may prove desirable with some unusually hard water supplies which interfere with the normal action of the wetting agent in the sulfur fungicide. Frequent coverage has proved the better answer to the problem of maintaining an adequate load of sulfur during the critical early period when rapid growth accounts more for the rapid loss of fungicidal protection than does weathering of the residue.

Peaches should receive 5 pounds of sulfur per 100 gallons of spray in each of four applications, beginning about two and a half to three weeks after the shuck spray as protection against peach scab and brown rot. The amount indicated may be supplied either with 5 pounds of a dry wettable product, or an equivalent amount of sulfur in the form of flotation sulfur, dry mix, or self boiled lime-sulfur. Liquid lime-sulfur cannot be safely used on peaches. Hydrated spray lime, 5 pounds per 100 gallons, should be used with wettable and flotation sulfurs except in the pre-harvest application where a reduced amount of sulfur is used alone. No additional lime is necessary where sulfur is used in combination with zinc sulfate and lime, the amount of lime normally used being greatly in excess of that required for the neutralization of the zinc sulfate.

The elemental sulfurs are not recommended for use on sweet or sour cherries except where necessary for the control of brown rot. They are not effective against cherry leaf spot, the most important cherry disease.

SUMMARY

Sulfur is the principal fruit fungicide in use today. The material is utilized both in the form of lime-sulfur and the elemental or wettable sulfurs.

Lime-sulfur is the most effective fungicide available for use early in the season, and is highly effective against apple scab, a disease that starts early in the growing season. It is the only fungicide that will burn out early season scab infections, but it is not a good cover spray fungicide because of its scalding and caustic properties. Liquid lime-sulfur has three principal disadvantages, the importance of which will vary in accordance with the situation existing where it is to be used. (1) The material is caustic and frequently causes injury to young developing fruit and foliage; (2) the shock effect of the material may reduce fruit set under certain conditions; and (3) lime-sulfur seriously reduces the effectiveness of lead arsenate when used in combination with it.

Dry lime-sulfur is produced from liquid lime-sulfur and is a good fungicide, but not equal to the liquid form. The material must be used on an active ingredient-equivalent basis with liquid lime-sulfur for scale control.

Sodium sulfur and potassium sulfur (liver of sulfur) are little used as they have no conspicuous advantages to offset their higher cost and lower range of insecticidal effectiveness.

The wettable sulfurs are mild and generally safe sulfur fungicides. Their effectiveness is closely correlated with the fineness of the sulfur particles of which they are composed, although none of them are as effective as liquid lime-sulfur. Flotation sulfur is the finest and most effective of the elemental sulfurs, followed by the Grinrod, Micronized, and the roller mill ground products. The elemental sulfurs may be used in the first two or three cover sprays without danger of spray injury except under very hot, dry weather conditions. They may safely replace Bordeaux mixture for these sprays, but should not be relied upon to control bitter rot or blotch. The elemental sulfurs do not interfere with the action of lead arsenate nor do they combine with it. No sulfur material can be safely used with or closely preceding summer oil.

Elemental sulfur is universally used as the peach fungicide, being used as wettable products, flotation paste, dry-mix and self-boiled lime-sulfur. The peach does not require as fine a product for satisfactory performance as does the apple.

The proprietary products commonly offered in Virginia are classified according to their adaptability to Virginia requirements. The most effective are suitable for post-blossom use on all apple varieties, and in all sprays on non-scabby apple varieties where frequent and thorough coverage can be given. A second group of slightly coarser materials is adapted to post-blossom and

cover spray use. A third group is dependable only for cover sprays. A fourth group includes those suitable for peach fungicides and for use on apples where very low fungicidal efficiency is acceptable.

Lime-sulfur remains the cheapest and most effective fungicide for use on apples in Virginia, but from the standpoint of safeness it is surpassed by the elemental sulfurs. The latter products also can be safely used in the early cover sprays instead of Bordeaux mixture, thus conserving copper sulfate, of which copper is the metallic ingredient and is a critical war metal.